APPLICATION NOTE: DYACONLIVE FIRE WEATHER REPORT

September 2021

OVERVIEW

DyaconLive Reports are custom data summaries and analysis generated from station measurements. Each report targets a particular type of environmental assessment such as agricultural degree days (see GDD App Note). Several reports are currently available and can be accessed via the Data page on DyaconLive.

The Fire Weather Report utilizes station measurements to assess the likelihood of a wildfire at the station location. The report analyzes air temperature, humidity, wind speed and precipitation data from the past 5 days, displaying fire and drought indices in charts (figure 1). While the calculations and data displayed in the report are highly valuable to assessing fire danger, it should be noted that the report is simplified relative to state sponsored fire danger systems such as the National Fire Danger Rating System used in the USA (Schlobohm and Brain 2002). The Dyacon Fire Weather Report is intended as one component in a broader assessment of regional fire danger.

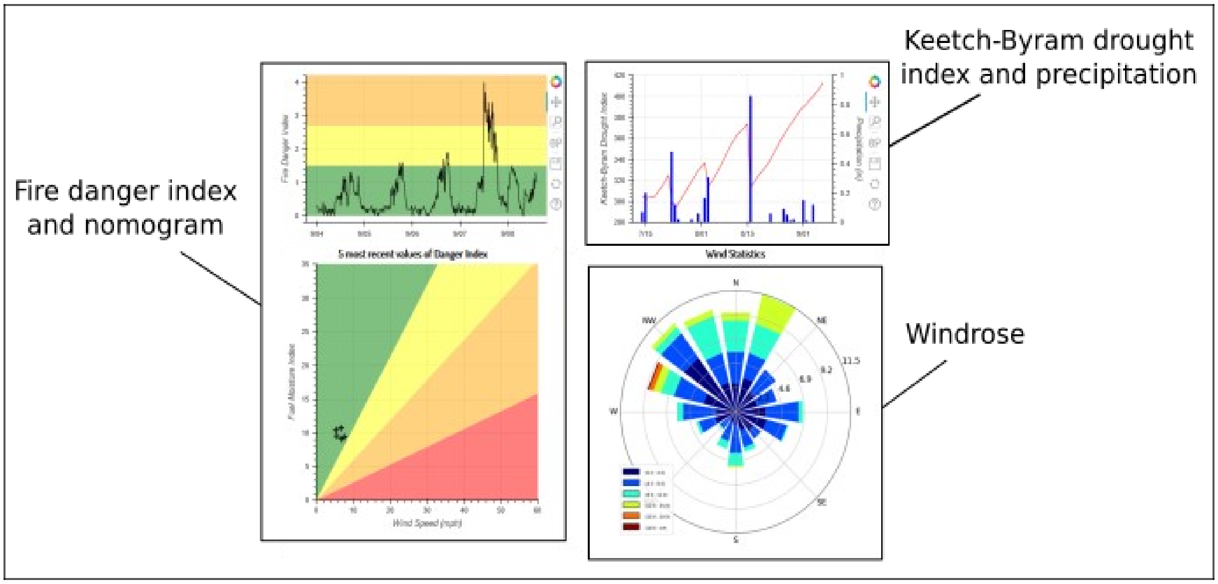

Figure 1: Fire Weather Report Charts

FIRE WEATHER SCIENCE

Prediction and modeling of wildland fires is an active area of research, especially due to the high cost of fires to humans and the natural environment. Two broad categories of fire science are assessing fire danger and predicting fire behavior. In both cases, weather data is critical, however, the Fire Weather Report focuses strictly on fire danger. Assessment of fire danger involves characterizing the probability that a fire will ignite and spread in a given area (Schlobohm and Brain 2002, Sharples *et al.* 2009).

There are three key components to fire danger:

- Fuel characterization – The type and moisture level of fuel present.
- Weather conditions – These influence both fire ignition and spread.
- Topography – Influences fire behavior.

Since topography is site specific and is not currently characterized by Dyacon stations, it is not included in the report and should be assessed independently.

FUEL CHARACTERIZATION

Fuels are any sort of biomass or combustible material that could potentially burn in a fire. It is common for fuels to be described broadly in terms of location (surface, canopy) or general type (shrub, herb, log, duff). Fuels properties like: size, shape, surface area, and moisture content affect both fire ignition and behavior during combustion (Keane 2015). Fuel can be alive or dead and this distinction influences how it is assessed (as discussed below).

Fuel moisture is one of the most important properties because it has an influence on all fire behavior including ignition, combustion, and smoldering (Keane 2015). High levels of fuel moisture inhibit ignition and reduce flame temperatures during combustion (Keane 2015). The factors controlling fuel moisture levels are much different depending on if the fuel is live or dead. Live fuel moisture levels are driven by a number of variables relating to plant ecophysiology including soil moisture, species, age of growth, and ambient weather conditions. Dead fuel moisture levels are a function of ambient environmental conditions. Moisture in a dead fuel particle will evaporate until an equilibrium is reached for a given combination of temperature and humidity. Often "equilibrium fuel moisture" is never achieved as the environmental conditions change too rapidly (Keane 2015). Nevertheless, equilibrium fuel moisture is a key input to assessing fire danger because it makes modeling fuel moisture easier by reducing the need for historical data.

FIRE WEATHER

Table 1 shows how different weather parameters affect fire danger.

Measurement	Significance for Fire Danger
Air temperature	Temperature, along with humidity, determine equilibrium fuel moisture content (Sharples *et al.* 2009(b)). It is also a component of Keetch-Byram which is used as a proxy for soil moisture content.
Relative humidity	The ambient RH determines equilibrium fuel moisture and therefore influences how easy it is for ignition to occur (Sharples *et al.* 2009(b)).
Wind speed	Wind is a "critical meteorological factor affecting fire" (Sharples *et al.* 2009). Not only does it determine direction of fire spreading, it pushes flames closer to fuel, supplies oxygen, caries away moist air.
Precipitation	Obviously, on a short term basis, precipitation is going to influence fuel moisture content and will help cool/extinguish a pre-existing fire. On a longer term basis, precipitation will determine soil moisture to some extent.
Soil moisture	Soil moisture content has an influence on live fuel moisture levels (Krueger *et al.* 2017, Keetch and Byram 1968). This results in a correlation between soil moisture and the incidence of large fires.

REPORT COMPONENTS

Figure 1 shows the different components of the Fire Weather Report. The charts on the left display a fire danger index (Sharples *et al.* 2009a, 2009b) with colors to indicate whether the index is low, medium, high, or very high (green, yellow, orange, red). The upper right hand chart show the Keetch-Byram drought index (Keetch and Byram, 1968) plotted with precipitation. Finally, a wind rose in the bottom right shows the frequency of different wind speeds in different directions for the last 5 days.

There are many different indices designed to characterize fire danger. In many countries, there are nationally sanctioned approaches for characterizing fire danger such as:

- USA: National Fire Danger Rating System (Schlobohm and Brain, 2002)
- Canada: Canadian Forest Fire Weather Index (https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi)
- Australia: McArthur Forest Fire Danger Index (https://en.wikipedia.org/wiki/McArthur_Forest_Fire_Danger_Index)

National danger ratings should be a primary part of any fire weather analysis where available, and the Fire Weather Report does not attempt to replace them. Instead the goal is to create a report that can be used worldwide and whose calculations are broadly understandable. With that in mind, the "Simple

Fire Danger Index" described be Sharples *et al.* 2009, is utilized in the report.

The approach used by Sharples is to first develop a simplified equation for fuel moisture (Sharples *et al.*, 2009(B)) that utilizes the essential components of more complex equations:

Fuel Moisture (FMI) = 10 - 0.25(T - H)

Inputs are T, air temperature in Celsius, and percent relative humidity H.

The danger index is then just a combination of the fuel moisture index and wind speed.

Fire Danger = $\max(U_o, U)/FMI$

U is the windspeed in km/hr and U_o is a threshold wind speed set to 1 km/hr.

The bottom line is that low fuel moisture and high winds lead to high fire danger. This is clearly shown using the nomogram below the fire danger index time series (figure 1). The current fire danger can be found in the nomogram using the current values of fuel moisture and wind speed. Recent danger index values are plotted on the nomogram to give a sense for what components of fire danger are changing.

The Keetch-Byram drought index (KBDI) (Keetch and Byram, 1968) is plotted as a line in the upper right hand chart. Daily precipitation is also plotted as bars. KDBI can be thought of as a proxy for soil moisture and is therefore relevant to assessing live fuel moisture. Index values range from 0 to 800 units where 0 represents a completely saturated soil column. A value of 800 indicates that the soil has an estimated water deficit of 8 inches. In desert climates the KBDI could theoretically exceed 800 but the value is capped at 800 since 8 inches of soil moisture loss is typically an extreme amount.

KBDI is calculated as a function of the prior day value (Q_{t-1}), max air temperature (T), and precipitation (P):

$$dQ = \frac{[800-Q]\,[.968\exp(.0486T) - .830]\,d\tau}{1 + 10.88\exp(-.0441R)} \times 10^{-3}$$

$$Q_t = Q_{t-1} - P + dQ_t$$

Mean annual precipitation (R) is a fixed site specific parameter that calibrates the equation for local vegetation water requirements. The calculation is typically run on a daily basis (dτ = 1)

Both a starting value for KBDI and the mean annual precipitation for the site must be determined when the Fire Weather Report is initially activated. The starting value can be tricky to determine depending on the location. In the USA, a value can be obtained from http://www.wfas.net/index.php/keetch-byram-index-moisture--drought-49. Another approach is to set the KBDI to 0 when the soil is known to be completely saturated due to heavy rains or snowmelt.

The value of KBDI may need to be manually adjusted if station data, particularly precipitation, is lost. Dyacon stations do not currently measure snow water equivalent, so KBDI values calculated during the winter in areas with significant snowfall will be wrong. At these sites, the KBDI chart should be utilized primarily in the summer months with the value manually set in the spring.

Finally, the wind rose chart is a polar plot showing wind speed and direction frequency for the past 5 days. A color gradient, from blue to red, indicates lower to higher wind speeds. For example, figure 2 shows that winds are out of the NNE about 10% of the time. There has also been brief high winds out of the WNW.

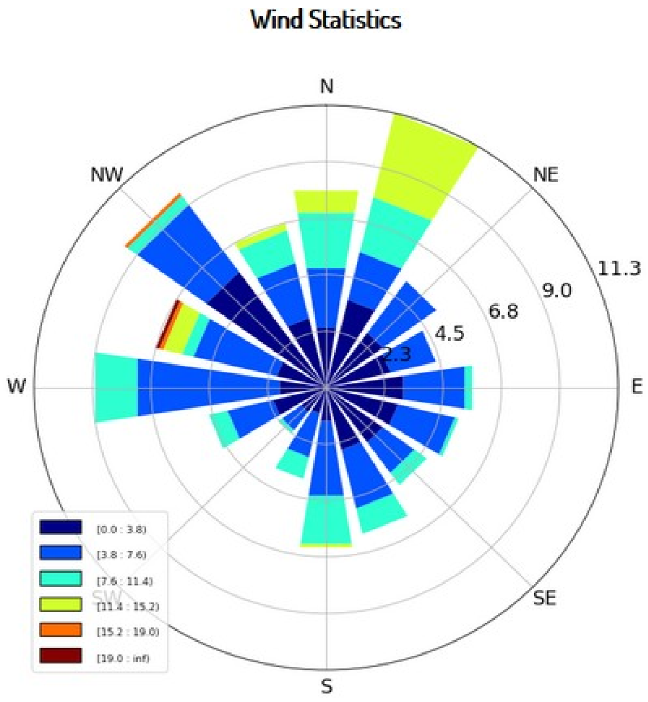

Figure 2

REPORT ACTIVATION

The Fire Weather Report is manually activated by Dyacon (contact support@dyacon.net). The station must be equipped with a precipitation gauge in addition to the basic measurements of temperature, humidity, and wind.

REFERENCES

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REVISION HISTORY

Rev	Description	Author	Date
A	Initial release.	C.Cox	9. Sept. 2021